B. H. CRAM.

APPARATUS FOR PRODUCING OXYGEN.

APPLICATION FILED MAY 25, 1915.

1,155,045.

Patented Sept. 28, 1915.

5 SHEETS—SHEET 1.

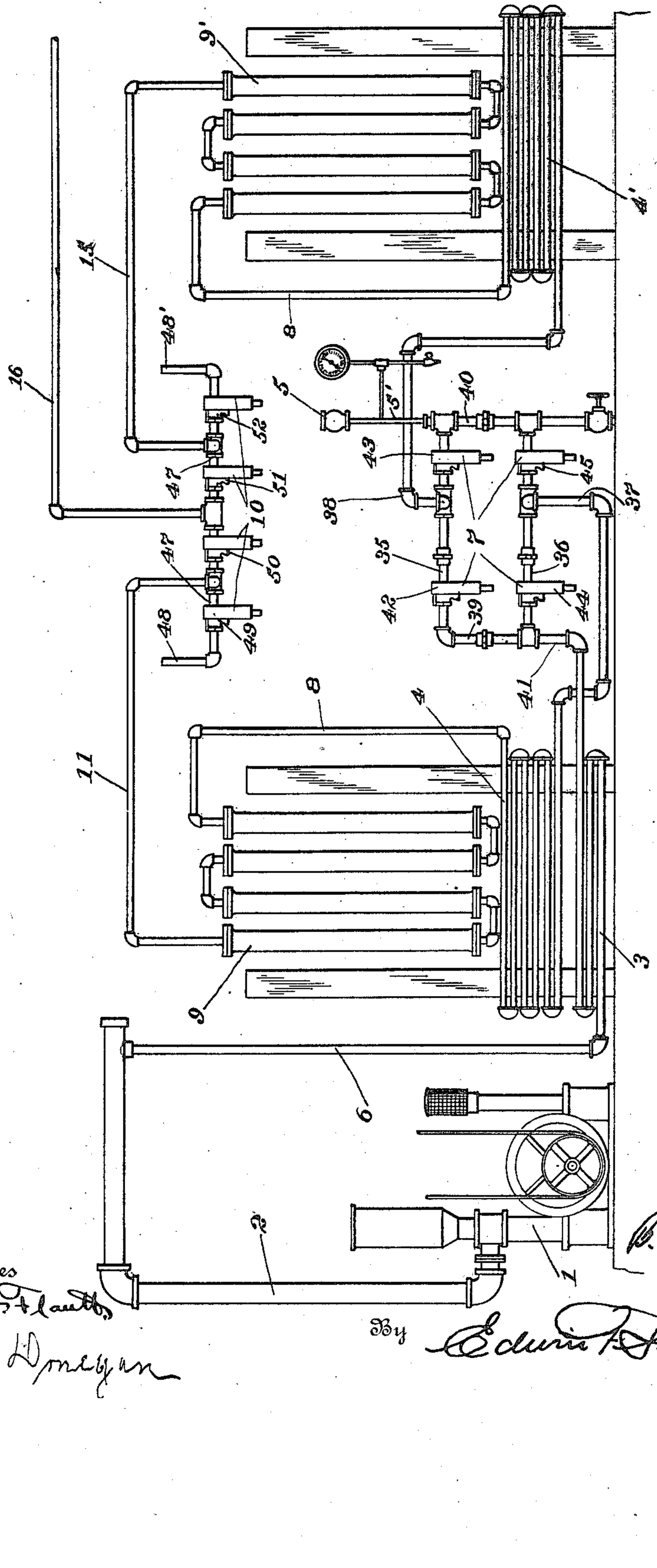


Fig. 1.

Witnesses

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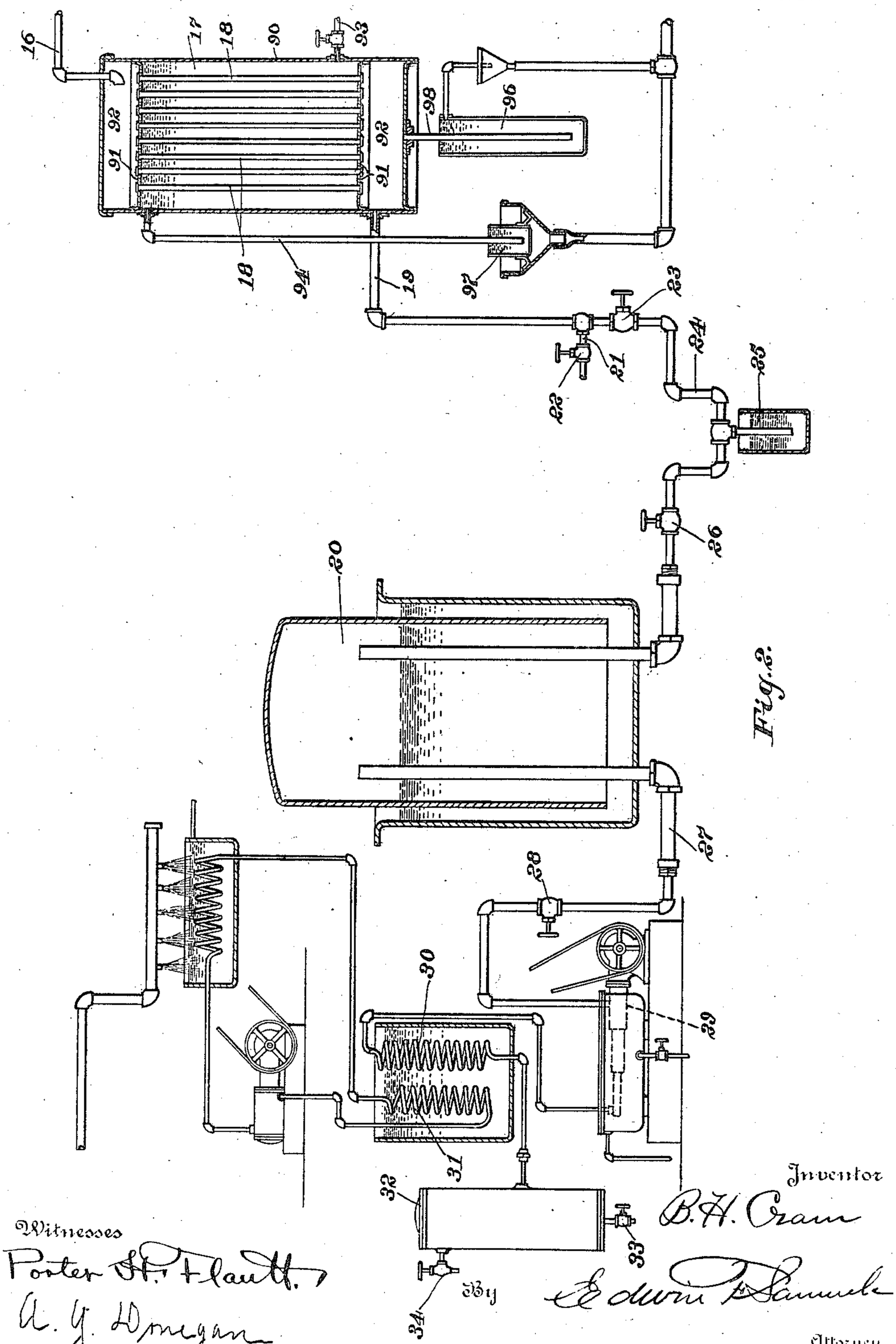


Fig. 2.

Witnesses

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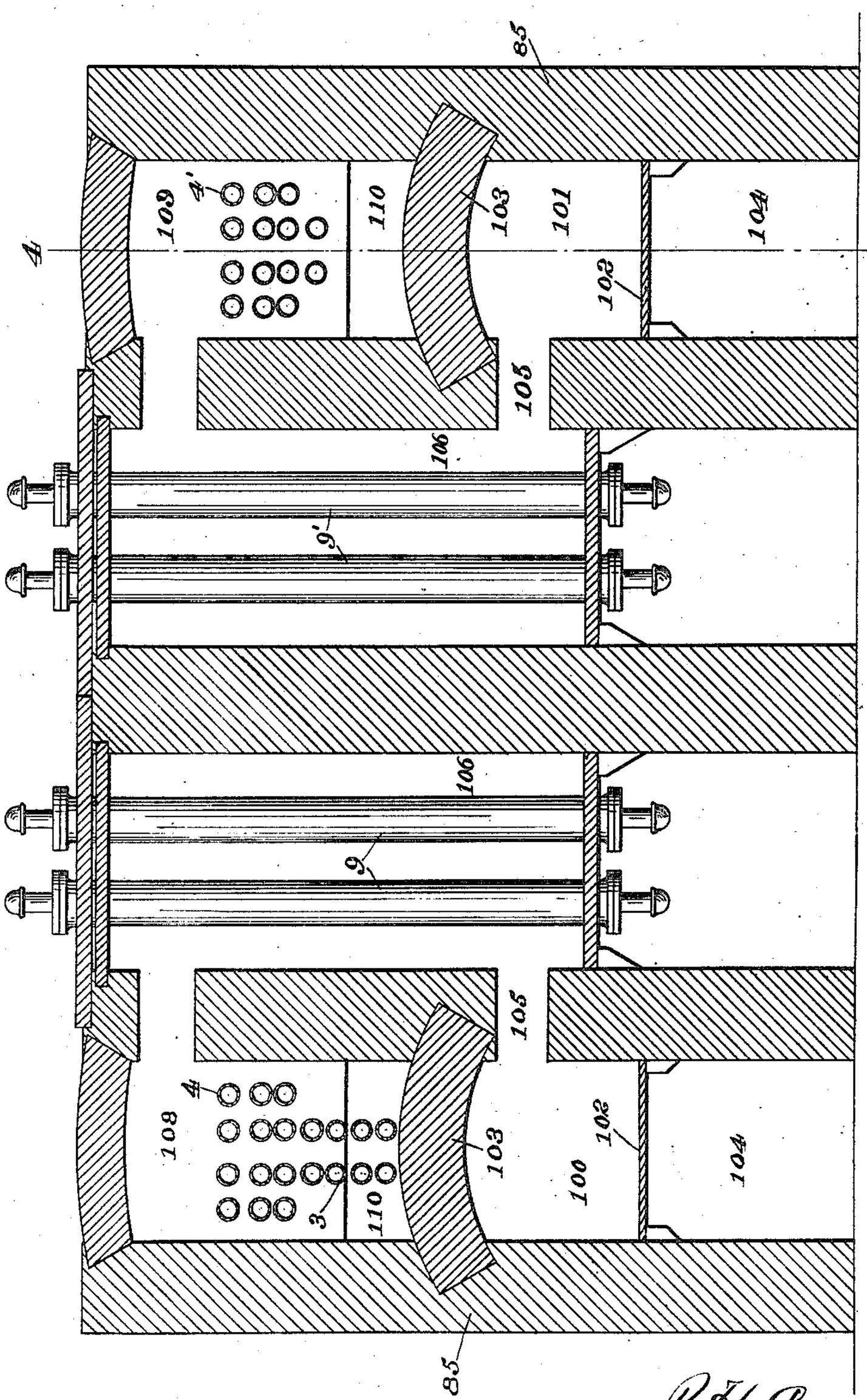


Fig. 3.

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5 SHEETS—SHEET 4.

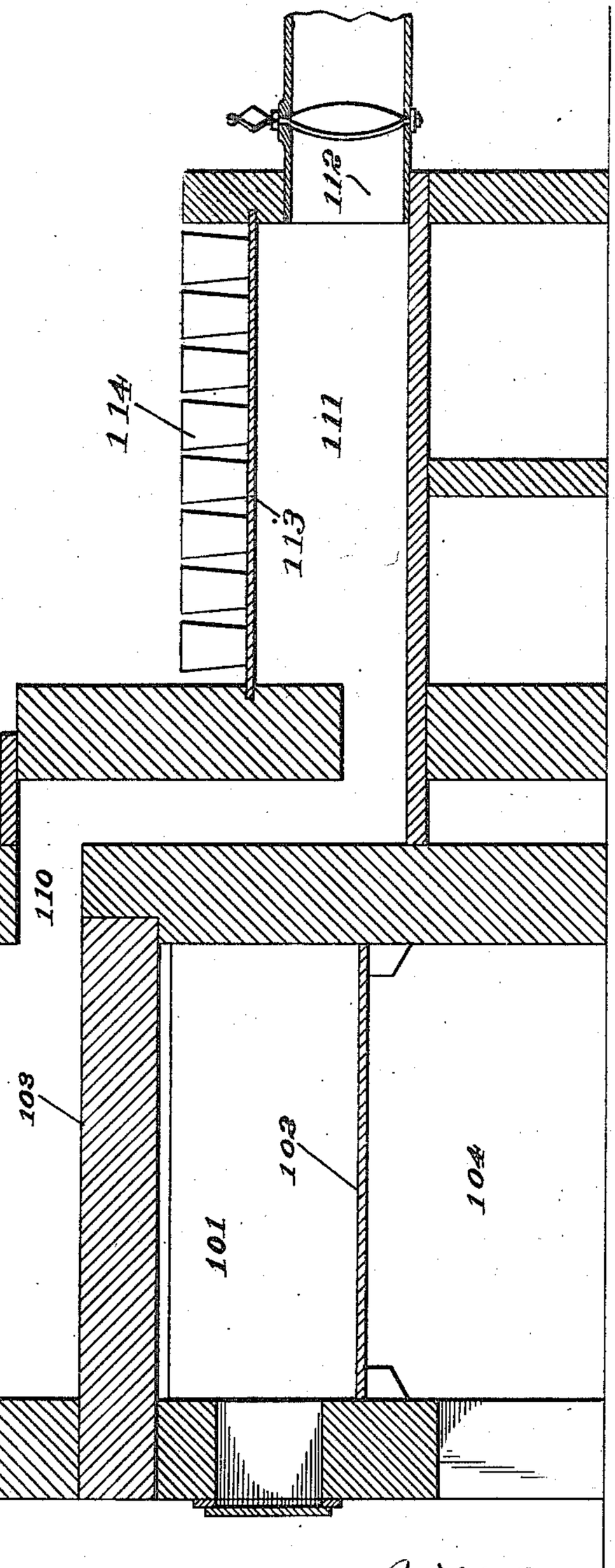


Fig. 4.

Witnesses

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5 SHEETS—SHEET 5.

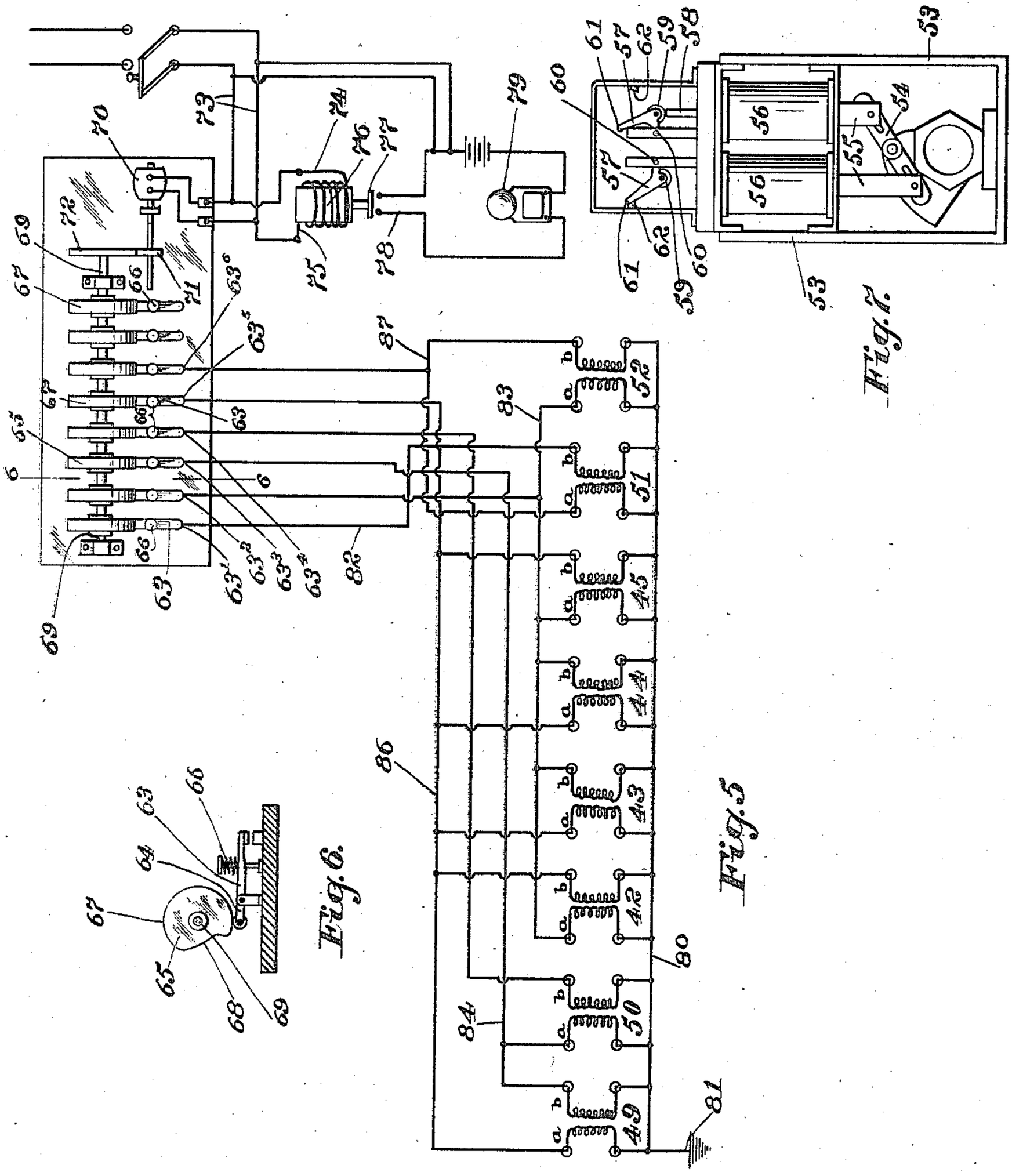

Fig. 5.



Fig. 6.



Witnesses

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# UNITED STATES PATENT OFFICE.

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## APPARATUS FOR PRODUCING OXYGEN.

1,155,045. Specification of Letters Patent. Patented Sept. 28, 1915.

Application filed May 25, 1915. Serial No. 30,295.

*To all whom it may concern:*

Be it known that I, BENJAMIN H. CRAM, a citizen of the United States of America, and resident of the city of Baltimore, State of Maryland, have invented certain new and useful Improvements in Apparatus for Producing Oxygen, of which the following is a specification.

The method of manufacturing oxygen by subjecting permanganate or manganate of soda, potash or the like to the alternate action of steam and air at a high temperature is widely known and has in the past been practised in several instances which are recorded in the literature of the art. However, though there is an extensive demand for oxygen, this process is not practised at the present time because it is not commercially successful.

The oxygen obtained by this process is carried over by superheated steam which decomposes the oxygen compound liberating the oxygen when the two are brought into contact at a high temperature, and the chemical is regenerated or oxidized by subjecting it to the action of air, also at a high temperature. The oxygen produced, in order to be commercially available, must be of a high percentage of purity, and in the past it has been impossible to produce anything approaching pure oxygen by this process. The difficulty is due to the fact that after passing air through the apparatus to oxidize the permanganate, the pipes and retorts are filled with air and when steam is introduced to resume the process of carrying over oxygen, it is necessary either to run this air into the product and thus reduce very considerably the percentage of oxygen, or blow it out by the waste or exhaust valve by means of the entering steam. To do this, the steam which is first brought in contact with the regenerated permanganate and which therefore carries a very large percentage of oxygen, must be permitted to escape. Theoretically, air can be passed over the permanganate to be regenerated and superheated steam passed through the apparatus and allowed to escape for a short period until the apparatus becomes clear of air. Then the steam is allowed to pass through a condenser and the oxygen is put into suitable carboys, without a loss so considerable as to make the cost prohibitive. However, viewed from a practical standpoint, the periods are so short and the action so rapid that it is difficult to operate the valves and produce the desired effect with any degree of regularity, or to obtain oxygen of anything approaching uniform purity, so that the operation, while theoretically possible, is in fact impractical from a commercial standpoint and the entire supply of oxygen now required for industrial purposes is made by other methods, as electrolysis or the liquefaction of air. In the present instance, this difficulty has been overcome and an apparatus evolved which is regular in its operation, producing a gas of a uniform and high percentage of purity. This is done by so arranging the connections from the steam and air supply to the retorts and from the retorts to the condenser and to the discharge that they can be conveniently controlled by suitable valves to lead the steam and air alternately over the desired paths for exactly the predetermined period of time, the valves being to this end automatically operated and timed.

Other improvements relate to the provision of a condenser so constructed as to prevent the introduction of outside air or air from the condensing water to the gas, and numerous refinements all tending to give the requisite efficiency to make the process commercially successful.

In the accompanying drawings I have shown so much of an apparatus for making oxygen by reduction and regeneration as is necessary to a full comprehension of the improvements which are the subject of this invention.

Figures 1 and 2 taken together constitute a diagrammatic showing of the system, the parts being shifted and rearranged so they can be projected into the plane of the paper without overlapping, the object being to show the retorts, gas, air and steam passages, condensers, etc., arranged in operative relation and as nearly as possible in the order in which they appear in the operative device; the furnaces do not appear in this diagram; Fig. 3 is a transverse vertical section showing the furnace, the coils and the retorts in two units of the plant; Fig. 4 is a section on the line 4, 4 of Fig. 3; Fig. 5 is a diagram of the electrical system; Fig. 6 is a detail of the cams for controlling the electric circuit; and Fig. 7 shows the valve actuating means in detail.

Referring to the drawings by numerals; the apparatus consists of a blower or air

pump 1 delivering air to the air main 2 from which it is led to an air heating coil 3. There are also steam superheating coils 4, 4′, one for each unit, the units being preferably arranged in pairs. Steam is supplied at 5 from any suitable source as a steam boiler. The air heating coil 3 is connected to the air main by a pipe 6 and this coil is connected at its opposite end to a system of piping and automatically controlled valves hereinafter described. These valves control the passage of the air from the hot air coil 3 so the heated air may be led through either one of the steam superheating coils 4, one of which forms a part of each of the units illustrated. Connected to the coils 4, 4′ by means of a pipe 8, in each unit, is a set of retorts 9, and I further provide suitable heating means as the furnace 85 by which all the parts are kept at a predetermined high temperature, for it must be borne in mind that the reduction and regeneration process by means of which the oxygen is obtained can only be carried on at high temperatures, and further that the air and all the parts of the apparatus with which the steam comes in contact must be heated to prevent loss by condensation. The material by the reduction and regeneration of which, the oxygen is produced, is placed in the retorts and there subjected at intervals, first to the action of superheated steam by which it is reduced, and then to the action of air by which it is regenerated, both actions taking place at a high temperature.

As we have stated, the apparatus is arranged in pairs of units or even numbers of units which operate alternately, that is the material in the retort of one unit or in the retorts of half the units, is being reduced by a current of superheated steam, while the material in the retort of the other unit or the other half of the units, is subject to the action of a current of air, also at a high temperature, and thus regenerated.

As is understood by those skilled in the art, the steam with the oxygen produced by the action of the steam on the chemical being reduced, is led to a suitable container, the steam is condensed, the gas compressed and all the water which can possibly be separated from the oxygen is removed, first in an ordinary condenser, the principal function of which is to remove the steam, and then by refrigeration after compression. However, the air which is passed over the charge to regenerate it, and the steam which is passed over the material for the first few seconds while the air left in the retorts and the rest of the system is being displaced, does not form a part of the salable product; in fact, if permitted to enter the condensing system and the containers, it would so dilute the gas as to prevent the manufacture of a merchantable product, so the air which is passed through the system and even the steam for the first few seconds of its flow is permitted to escape, either directly or through any suitable device for economizing the heat contained.

To distribute the heated air and steam to the retorts, there is a system of automatically controlled valves 7, and to provide for the escape of the air and the initial steam flow in each instance, as well as for the control of the passages by which the mixed steam and oxygen are led to the condenser, a system of automatically controlled valves 10 is used. In this latter system a pipe 11 is led from the retorts of the first unit and a pipe 15 from the retorts of the second unit. A pipe 16 connects the system 10 with the condenser. This pipe is preferably inclined toward the condenser to carry off the water condensed in the pipe. Referring particularly to Fig. 2 the pipe 16 leads the steam and oxygen from the retorts to the condenser 17, where it is passed through small tubes 18 which are subject to the action of a continuous flow of cooling water, but the water itself is not brought in contact with the gas. Direct contact of the water and gas is objectionable due to the fact that all water in its natural state carries a considerable amount of air and this water, particularly under the low pressure conditions which exist in this part of the apparatus, would give up enough of its air to make it impossible to produce oxygen of a high percentage of purity. The cooling effect of the condenser is sufficient to condense the live steam carrying the oxygen.

From the condenser, the oxygen is led by way of the pipe 19 to a suitable receptacle, as a water-sealed gasometer 20, shown as of a well-known type. In the pipe 19 at 21, I have shown a T with a valve 22 for use in testing and to permit the escape of the first part of the product in starting to avoid air and other impurities. There is also a valve 23 by which the storage end of the system may be closed when the valve 22 is opened. At 24 I have shown a U or depression with a trapped drip 25. Beyond the drip 25 is another gate valve 26 which may be closed to prevent back flow from the gasometer. Leading from the gasometer is a delivery pipe 27 with a valve 28 by way of which the oxygen is carried to a submerged compressor 29 from which the gas is passed through a coil 30 submerged in brine in close proximity to a refrigerating coil 31 from whence the oxygen is led to a suitable container 32 having an automatic drip 33. From the container means is provided in the way of valves and delivery outlets 34 for filling carboys or similar containers with the gas.

Referring again to Fig. 1, the steam su-

perheating coils 4 and 4′ are connected one to each of two parallel lines of piping 35 and 36, the connection of the coil 4 to the pipe 36 being made by means of a pipe 37, and the connection of the coil 4′ to the pipe 35 being made by means of a pipe 38. The two lines 35 and 36 are connected at their ends by pipes 39 and 40 constituting a manifold in the form of a loop or rectangle to one end of which the air coil 3 is connected by a pipe 41 and to the other end of which the source of steam 5 is connected by any suitable means, as a pipe 5′. In the pipe 35 on each side of the pipe 38, leading from the steam coil 4′, I have shown valves 42 and 43, and in the pipe 36, one on each side of the pipe 37 from the steam coil, I have shown valves 44 and 45. These valves are automatically controlled to operate at predetermined intervals in the desired sequence. As illustrated, they are electrically operated by means of solenoids, which, for the sake of convenience, are identified by means of the numbers applied to the valves, a set of two being provided for each valve.

Still referring to Fig. 1, the delivery pipes 11 and 15 leading from the retorts 9 and 9′, are, in the form of the invention shown, both led to a manifold 47 having a waste or exhaust outlets 48, 48′, at each end, and a delivery 16 leading from the center of the manifold 47 toward the condenser 17. To control the flow from the retorts, four valves 49, 50, 51 and 52 are provided in the manifold 47, the valves 49 and 50 being one on each side of the point where the pipe 11 joins the pipe 47, and the valves 51 and 52 being one on each side of the point where the pipe 15 joins the pipe 47, so that the valves 50 and 51 are one on each side of the delivery pipe 16. In this way, the valve system 7, including the valves 42, 43, 44 and 45, controls the flow of air and steam to the retorts 9 and 9′, and the valve system 10, including the valves 49, 50, 51 and 52, controls the delivery of air, oxygen and steam from the retorts to the condenser, and the unabsorbed air and the steam and oxygen which is mixed with air from the exhaust or waste pipes 48, and 48′.

In the present instance automatic means is provided for operating in unison the valves grouped at 7 and 10, opening and closing them and controlling the timing and sequence of their operation.

Referring to Fig. 7, which is an assembly on a large scale of the essential features of the electrical appliance by means of which each individual valve is operated, the entire mechanism of each valve is inclosed within a casing 53 and each valve, in the form of the invention shown, is operated by a transverse centrally pivoted lever 54 having a pin and slot engagement at each end with one of the cores 55 of two solenoids 56, one for opening and the other for closing the valve. In connection with each solenoid there is a trigger or tripping device 57 by means of which the current is made and broken independently of the automatically operated controller which is in circuit with the solenoids of all the valves. The trigger 57 in each instance, is tripped by an upright stud 58 with which each core is provided. The valve mechanism is so arranged that when there is no current, it is in equilibrium and stationary. As soon as one coil is energized, the core which coöperates with that coil is drawn up, the corresponding end of the lever 54 is lifted, the lever is swung about its pivot and the valve opened or closed as the case may be. As the core moves up toward the end of its normal stroke, the stud or pin 58 comes in contact with a roller 59 on the trigger 57 and breaks the circuit by swinging the trigger about its center 60 and moving the end of the trigger at 61 from the contact point 62 on the frame; at the same time, the other trigger is released and falls into contact. In this way, the circuits of the two solenoids are made and broken alternately in accordance with the timing of the controller, the triggers being returned by gravity to normal which is the closed circuit position.

In Figs. 5 and 6, I have illustrated the controller and shown diagrammatically the plan of the circuit by means of which the solenoids operating their respective valves are energized in turn to open and close the valves in the desired sequence. To this end, I provide switches 63, distinguished at 63′ to 63⁶, by means of which the circuit, including the solenoid for actuating each valve, is controlled. Each switch forms part of a cam lever 64 provided with a suitable follower operating in connection with rotary cams 65. Springs 66, one for each cam, tend each to close the corresponding switch and keep the follower in contact with the cam. Each of the cams has a circular periphery 67 broken by a short depression or recess 68. When a roller or follower enters the recess of its cam, the spring 66 closes the switch and the current passing through the circuit energizes the corresponding solenoids and operates the valves. There are six of the cams 65 shown in operative connection with the circuit and two extra cams not connected, shown as mounted on the single cam shaft 69. The cams are set at a suitable angle and the shaft is operated by means of a motor 70 connected to the shaft 69 by means of toothed gears 71 and 72. The motor in turn is supplied with current from any suitable source by way of connections 73, and driven at a constant speed. Shown as shunted across the motor at 74, there is a coil 75 which, when the circuit 73 is energized, supports the core 76 which carries a

switch 77 forming part of a battery or other relay circuit 78 in which there is a valve or other alarm 79. If, for any reason, the motor circuit is broken, the core 76 will drop, close the circuit 78 and operate the alarm. The battery circuit may also be connected to the motor circuit as shown, to take the load for a short time when the main current is off. In this way the excessive losses which might result from interruption of the circuit are avoided.

Referring to Fig. 5, the solenoids, two for each valve, are for convenience numbered according to the corresponding valves. In the arrangement shown, the left-hand coil *a* in each instance, when energized, serves to open the valve, and the right-hand coil *b* to close it. In Fig. 5, the circuit is shown diagrammatically. The diagram includes a main 80 to which each solenoid is connected. This wire is grounded at 81. The switches 63 are distinguished as $63'$, $63^2$, $63^3$, $63^4$, $63^5$, and $63^6$. The switch $63'$, as shown, is connected by a wire 82 to the closing solenoid *b* of the valve 51; the switch $63^2$ is connected to a main 83 which in turn is connected to the opening solenoid *a* of valves 42, 45 and 52 and to the closing solenoids *b* of the valves 43 and 44; the switch $63^3$ is connected to a main 84 which is in turn connected to the opening solenoid *a* of valve 50 and the closing solenoid *b* of valve 49; the switch $63^4$ is connected to the closing solenoid *b* of valve 50; switch $63^5$ is connected to a main 86 from which there are leads to the opening solenoids *a* of valves 43, 44 and 49 and to the closing solenoids *b* of valves 42 and 45; and switch $63^6$ is connected to a main 87 from which there are leads to the opening solenoid *a* of valve 51 and the closing solenoid *b* of valve 52.

In explaining the operation of the valves, the retorts and the superheating coils, it will be assumed that the chemicals in the retorts 9 of the first or left-hand unit, are being regenerated. The air used is heated in the coil 3 so that it will not cause condensation of the steam when the process is reversed, and steam is passed through the same pipes and retorts. The heated air from the coil 3 is led through the superheating coil 4 and by way of the pipe 8 through the retorts 9 and out by the delivery pipe 11 to the waste or exhaust 48. At the same time steam is being passed from the source by way of the pipe 38 to the superheater $4'$ and thence through the retorts $9'$ where it takes up oxygen and passes by way of the delivery pipe 15 to the pipe 47 and by way of the pipe 16 to the condenser.

When the chemicals in the retorts $9'$ have been reduced and those in the retorts 9 oxidized to an extent determined by experiment and found to be in accord with the most efficient operation, the paths of the steam and air currents are interchanged, that is, the heated air from the coil 3 is passed through the steam superheater $4'$ and through the retorts $9'$ whence it is permitted to escape from the waste opening $48'$. The steam from the source 5 is passed through the superheating coil 4, the retorts 9 and the delivery 11, but as the retorts 9 and the coil 4 are at this time filled with air which, if it were mixed with the supply of oxygen, would so dilute the product as to destroy its commercial value, it is necessary to displace the air content of this portion of the system with steam before the product is turned into the regular channel, and to this end, the air and the steam which first traverses the retorts and passages must be permitted to escape from the exhaust 48.

To bring about the first condition described, in which air is passing through the coil 3, the steam superheating coil 4 and the retort 9, escaping through the exhaust 48, and steam through the coil $4'$ and the retorts $9'$, passing by the delivery pipes 15 and 16 to the condenser, the valves 44, 49, 43 and 51 are open and the valves 42, 45, 50 and 52 are closed. During this operation, as has been previously pointed out, the material in the retorts 9 is being oxidized and that in the retorts $9'$ reduced, the waste air from which the supply of oxygen has been taken escaping at 48, and the steam with the oxygen which has been produced being carried to the condenser from the retorts $9'$ by way of the pipes 15 and 16.

In the next condition of operation, steam is passed through the superheating coils 4 from the retorts 9, taking up oxygen from the regenerated materials in the retorts 9, and air is led by way of the coils 3 and $4'$ through the retorts $9'$ and back to the open air through the exhaust $48'$. In order to prevent the air which is left in the retort 9 and the pipes forming part of the first unit from entering the container with the oxygen, it is necessary to displace all the air in this part of the system by means of the entering steam, and to do this, not only the air content of the system but a portion of the steam is permitted to escape into the open air by way of the exhaust opening 48, so that the next operation of the valve systems merely alternates or interchanges the paths followed by the steam and air in the two units up to where the two currents enter the pipe 48, and for a short period both units exhaust by way of the waste openings 48 and $48'$ respectively. Therefore, in the next position of the valves, 42, 52, 45 and 49 are open and 43, 44, 50 and 51 are closed. During this operation, as stated, the steam and air from the retorts 9 and the pipes of the first or left-hand unit, are escaping through the waste opening 48.

When the air has been cleared from the

retorts and pipes in the first system, which occupies but a few seconds, the position of the valves must be changed so as to terminate the flow from the waste 48 and admit the steam and oxygen to the delivery pipe 16, so that after the lapse of a comparatively short period, the valve 49 is closed and the valve 50 opened.

The fourth operation corresponds to the second, that is steam is turned into the retorts 9′ and air into the retorts 9, the air escaping from the waste 48 and for the first part of the period, steam and air from the retorts 9′ escape by way of the waste 48′. In the fourth position of the valves which gives this operation, the valves 44, 49, 43 and 52 are open and valves 42, 45, 50 and 51 are closed. Under these circumstances, air heated in the coils 3 and 4 is passed through the retorts 9 and out of the waste opening 48, regenerating the chemical in the retorts 9, and steam from the source 5, superheated in the coils 4′, is passed through the retorts 9′. For a short period, it is necessary to blow out the steam and air from these retorts to prevent passing the air into the oxygen which forms the product, and for this reason the steam, oxygen and air from the retorts 9′ are permitted to escape from the outlet 48′, but after a very short time, the escape of the steam and oxygen from the waste 48′ must be terminated and the product passed by way of the delivery 16 to the condenser, so that the next operation, which takes place almost immediately consists in the closing of the valve 52 and opening of the valve 51.

As has been fully described in connection with the wiring diagram, Fig. 5, there is a series of switches 63 operated by a series of cams 67 controlling a series of solenoids, one to open and one to close each valve. Each switch controls a single solenoid or a group of solenoids, connected in parallel, as the case may be. Where a number of operations, either opening or closing take place simultaneously in every instance, the corresponding coils are connected in parallel and controlled by a single switch operated by a single cam. In connection with the two units shown, there are six different groups or sets of operations requiring that the solenoids be connected in six groups so that there are six switches and six cams shown on a single shaft. The wiring diagram and analysis of the valve operations show that in the present instance, the valves 49, 43 and 44 are opened and the valves 42 and 45 are closed simultaneously. The valves 42, 45 and 52 are opened and the valves 44 and 43 are closed simultaneously. The valve 50 is opened and the valve 49 closed simultaneously in each instance. The valve 52 is closed and the valve 51 opened simultaneously in each instance. The valves 51 and 50 are separately operated in closing and require each a separate cam and separate switch. Each set of simultaneous operations is accomplished by a single cam and switch as shown.

It will thus be apparent that the passage of steam and air through the apparatus when once determined as to time and sequence, can be conveniently accomplished as described and can be repeated indefinitely with absolute regularity, so that a product of uniform and maximum purity can be produced.

The mixed steam and oxygen from the retorts is led by way of the delivery pipe 16 to the condenser 17 where the mixture is cooled and the steam condensed and drawn off in the form of water. The condenser illustrated is particularly adapted for use in connection with this process in that the cooling effect resulting from a continuous supply of water is obtained without bringing the product in contact with the water, for it will be understood that contact of the oxygen with water is objectionable as all water in its natural condition contains a considerable amount of air some of which is released at the condenser pressure.

The condenser, as shown, consists of a drum or cylinder 90 with headers or partition plates 91 near the top and bottom, but spaced from the top and bottom heads to provide gas chambers 92. These chambers are connected by small tubes 18 and the intermediate space around the tubes and between the headers 91 is filled with water, supplied by way of the pressure pipe 93, and led off from the condenser by way of the overflow 94, the latter shown as of considerably greater capacity than the supply pipe 93 having its intake just below the top header 91. The gas pipe 16 from the retorts enters the top chamber and the gas is withdrawn by way of the pipe 19 leading from the bottom chamber. The condensed water is removed from the bottom of the condenser by way of a suitable drip pipe 98 and both the drip pipe 98 and the outlet pipe 94 for the cooling water are provided with water seals 96 and 97 respectively to prevent access of air to the condenser. The water seal 96 prevents the flow of air directly into the gas chamber. The seal 97 is to prevent the access of air to the cooling water space. This is provided in view of the fact that a slight vacuum is set up in the gas space of the condenser and with any considerable amount of air in the cooling water space, a leak in the condenser would admit air to the gas and cause serious loss of value in the product.

The functions of the valves 22, 23, 26 and 28, the gasometer 20 and the drip 25 will be understood by those skilled in the art, par-

ticularly in view of the descriptive matter on this point already introduced into this specification; also the function of the compressor 29 submerged in water to obviate the necessity for lubrication by means of oil which cannot be used in the presence of oxygen under pressure. The advantage of further cooling to remove moisture after compression will also be understood and the details of the refrigerating apparatus already described in a general way, are not of importance in connection with this disclosure.

As I have stated, Fig. 1 is not an actual view of any known form of the apparatus. It is merely a diagram showing the relation in which the coils and retorts are connected to each other and to the manifolds 35, 36, 39 and 40 and the manifold 47. No actual view of the apparatus as set up would show the relation of these parts to advantage, but in Fig. 1 an element of the apparatus associated immediately with the retorts and coils 3 and 4 is not shown. Each unit or set of coils and retorts is installed in a suitable furnace by which the air and steam are brought to the temperature at which they may be used to the best advantage in reducing and regenerating the chemicals used. Two furnaces combined in the relation in which they would be used for heating the two units described are shown in transverse cross section in Fig. 3 and a longitudinal section through one furnace is shown in Fig. 4. The battery of furnaces illustrated in Fig. 3 comprises two combustion chambers 100 and 101, each having a grate 102 and being surmounted by a firebrick arch 103. In the form of the invention shown, a forced draft is used, the air being drawn from the ash pits 104 through the grate, outward laterally through an opening 105 into a chamber 106 in which are located the retorts 9 and 9′. From this chamber hot gases pass into a second chamber 108 in the left-hand unit and 109 in the right-hand unit. The chamber 108 contains the air heating coil 3 and steam superheating coil 4, and in the chamber 109 is a steam superheating coil 4′. The products of combustion are exhausted through a stack or suitable exhaust opening 110.

Fig. 4, as shown, is a section on the line 4, 4 of Fig. 3. By reference to this figure it will be seen that the exhaust opening 110 is connected to a chamber at the rear of the furnaces, indicated at 111, which in turn leads to the damper and flue by way of an opening 112. This chamber is surmounted by an iron plate 113 and a grid 114 by means of which the exhaust gases are utilized in the preparation of the permanganate used in the retorts. By heating a mixture of oxid of manganese and caustic soda in this way, the permanganate used in the retorts may be prepared in a convenient and economical manner, and this apparatus may be utilized in reclaiming the exhausted materials.

The operation of the entire apparatus has been fully described.

While the manufacture of oxygen by the reduction and regeneration of permanganate and similar materials has not been practised commercially because sufficiently pure oxygen could not be produced at a reasonable cost, this process is made practical by this apparatus. The losses due to the irregular operation of the valves by human agency are avoided. In this way I not only avoid loss but am enabled to produce oxygen of a uniform degree of purity at a cost much reduced as compared to the cost previously involved in the practice of similar methods and less than that of the existing electrical and compression methods. Improvements in the other features have eliminated other sources of loss and as a result, a method of manufacture which has recently been considered capable of use only in a laboratory, is made commercially available.

I have described in detail numerous features of my apparatus which are not essential to the invention in order that the disclosure may be sufficiently full and complete to enable those skilled in the art to build the apparatus and operate it. However, I do not desire to limit my claims to the specific details described.

What I claim and desire to secure by Letters Patent is:

1. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, a retort for the oxygen compound, means for heating the retort, means for passing heated air and superheated steam alternately through the retort, valves for alternating the path of the air and steam and automatic means for operating the valves, equalizing the period and maintaining the sequence of operation.

2. In an apparatus for making oxygen by decomposition and regeneration of material containing oxygen, a plurality of retorts for the material containing oxygen, means for leading heated air and superheated steam alternately to the retorts, a manifold, means connecting the retorts to the manifold, a condenser, means connecting the manifold to the condenser, an exhaust outlet for the manifold, valves in the manifold for controlling the passages from the retorts, and automatic means for operating the valves and determining their sequence of operation whereby steam and oxygen are led to the condenser and the air is permitted to escape.

3. In an apparatus for making oxygen by the decomposition and regeneration of an oxygen compound, retorts for the oxygen compound, an exhaust manifold, pipes lead-

ing from each retort to the exhaust manifold, a condenser, a pipe leading from that manifold to the condenser, a supply manifold, means for superheating steam and air and leading them to the retorts, means in the supply manifold for controlling the passage of steam and air to the retorts whereby the retorts are alternately supplied with superheated steam and hot air, valves in the exhaust manifold, and automatic means for operating the valves in both manifolds and controlling the sequence of operation of said valves, whereby the air admitted to each retort in turn is permitted to escape into the outside air, and the steam and oxygen combined are led to the condenser.

4. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, retorts for the oxygen compound, means for heating the retorts, means for passing heated air and steam alternately through the retorts, means for alternating the paths of the air and steam, and automatic means for operating said means, equalizing the period and maintaining the sequence of operation.

5. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, retorts for the oxygen compound, means for heating the retorts, means for passing heated air and steam alternately through the retorts, means for alternating the path of the air and steam, automatic means for operating said means, equalizing the period and maintaining the sequence of operation, a condenser, a compressor and refrigerating means for cooling the gas after it has been compressed.

6. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, a retort for the oxygen compound, means for heating the retort, means for passing heated air and steam alternately through the retort, means for alternating the path of the air and steam, automatic means for operating said means, equalizing the period and maintaining the sequence of operation, and a condenser, having means for preventing the access of the water to the gas space.

7. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, a plurality of retorts, steam superheating means, means for heating air, a delivery manifold, delivery pipes leading from the retorts to said manifold, a condenser, means for leading mixed steam and oxygen from the delivery manifold to the condenser, waste outlets in the delivery manifold, a valve controlling each delivery pipe, valves and automatic means for actuating the valves to control the steam and air passages to alternate the flow of air and steam through the retorts and to permit the escape of the waste air and to lead the mixed steam and oxygen to the condenser, the valves and actuating means being arranged to cause the initial flow of steam in each instance to blow the air out of the retorts by way of the waste.

8. An apparatus for making oxygen consisting of a plurality of retorts and means for heating them, a delivery manifold 10 and a steam and air controlling manifold 7, air heating means and steam heating means for each retort, delivery pipes connecting the delivery manifold to the retorts, a condenser, means for leading the product from the delivery manifold to the condenser, means connecting the air heating coil and each steam heater to the distribution manifold and each steam heater to the corresponding retort, valves in the delivery manifold controlling each delivery pipe, exhaust outlets from the delivery manifold, a valve controlling each exhaust outlet, and valves in the distribution manifold controlling the steam and air passages, and automatic means for opening and closing the valves and controlling the sequence of their operation to lead steam and air alternately to the retorts, to exhaust the waste air from the delivery manifold and lead mixed oxygen and steam to the condenser, the valves being timed to provide for the blowing out through the exhaust of the waste air from each retort during the initial portion of the steam flow.

9. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, retorts for the oxygen compound, means for heating the retorts, means for passing heated air and superheated steam alternately through the retorts, valves for alternating the path of the air and steam, automatic means for operating the valves, equalizing the period and maintaining the sequence of operation, said means being electrically operated, the circuit including a coil connected to each valve, means for controlling the electrical condition of each coil and a motor for operating said means.

10. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, a retort for the oxygen compound, means for heating the retort, means for passing heated air and superheated steam alternately through the retort, valves for alternating the path of the air and steam, automatic means for operating the valves, equalizing the period and maintaining the sequence of operation, said means being electrically operated, two coils for each valve, means for connecting the coils to the valves, one coil serving to open and the other to close the corresponding valve, a source of electricity and connections whereby the coils are connected in groups, a switch for each group to operate the coils

in that group simultaneously, a cam operating each switch, a single shaft upon which the cam is mounted, an electric motor connected to the shaft to rotate it, and means for operating the motor at a constant speed.

11. In an apparatus for making oxygen by decomposition and regeneration of an oxygen compound, retorts for the oxygen compound, means for heating the retorts, means for passing heated air and superheated steam alternately through the retorts, valves for alternating the path of the air and steam, automatic means for operating the valves, equalizing the period and maintaining the sequence of operation, said means being electrically operated, a plurality of coils for each valve, means for connecting the coils to the valves, each to operate the valve when the core is energized, one coil serving to open and the other to close the corresponding valve, a source of electricity and connections whereby the coils operating the respective valves simultaneously are connected in groups, a switch for each group, a cam operating each switch, a single shaft upon which the cam is mounted, an electric motor connected to the shaft to rotate it, the motor operating at a constant speed.

12. In an apparatus for making oxygen by decomposition of an oxygen compound, a plurality of retorts for the oxygen compound, means for leading heated air and superheated steam alternately to the retorts including a supply manifold, means for leading superheated steam and heated air to the supply manifold, a delivery manifold, a container for gas connected to the delivery manifold, a waste outlet from the delivery manifold, pipes leading from each retort to the delivery manifold, valves in the delivery manifold controlling the exhaust and the passage to the container, valves in the supply manifold and means for controlling the valves, those in the supply manifold so that the air passage is closed before the steam passage is opened, and those in the delivery manifold so that the exhaust is closed before the passage to the container is opened, said means also controlling the passages to pass air and steam alternately through the respective retorts.

Signed by me at Baltimore, Maryland, this 24th day of May, 1915.

BENJAMIN H. CRAM.

Witnesses:
EDWARD L. BASH,
ALICE G. DONEGAN.